Harnessing environmental noise to control correlations in a quantum wire

Andisheh Khedri,
Antonio Strkalj, Alessio Chicchetta, Oded Zilberberg

Institute for Theoretical Physics, ETH Zurich, 8093 Zurich, Switzerland

akhedri@phys.ethz.ch

The Tomonaga-Luttinger liquid (TLL) is one of the cornerstones of many-body quantum physics, providing a unifying low-energy description of one-dimensional systems, regardless of their nature (bosons, fermions, spins). Such ubiquitous and fascinating physics shows up in carbon nanotubes, quantum Hall systems, organic molecular crystals, ultracold atoms, Josephson-junction chains, optical waveguides in proximity to Rydberg atoms, and many other systems. However, given the one dimensional nature of the TLL, its realisations naturally involve the presence of an environment (leads) coupled to its far ends. This is not only unavoidable but also essential to realise quantum transport across the wire. The nature of these leads can be very diverse, ranging from metallic gates with unscreened Coulomb potential, and phonons, to other complex RC circuits, to superfluid Fermi gases. Accordingly, understanding the impact of leads on a TLL is imperative from an experimental as well as theoretical point of view.

We assess the impact on the TLL properties of a broad class of leads, described by different Ohmic classes. Our main result is that the TLL universality class is deeply modified by the leads. To further highlight the consequences of the above, we consider the presence of a back-scattering impurity and we address the paradigmatic Kane-Fisher physics in this context. We find that the environment with fast fluctuations (super-Ohmic) makes the effective interaction at low-energies repulsive and the renormalized back-scattering potential becomes infinitely large as if the wire is cut in half. On the other hand, for the sub-Ohmic case, the slow fluctuations of the environment overtake the many-body effects of the quantum wire and the back-scattering from the impurity becomes irrelevant. Furthermore, we present the consequences of the above on realistic transport measurements and elaborate on the temperature scaling of the impurity-induced conductance for a finite quantum wire.

Figures

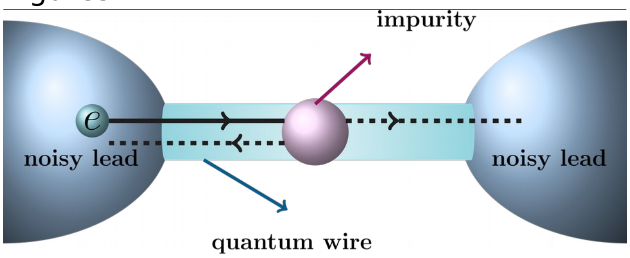

Figure 1:
Sketch of a quantum wire containing a single impurity, that back-scatters electrons. The is coupled to noisy leads at its two ends.

References

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